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PROJECT OFFICERS REPORT—PROJECT 2.13

RADIOISOTOPE FRACTIONATION AND PARTICLE SIZE CHARACTERISTICS OF A LOW-YIELD SURFACE NUCLEAR DETONATION (U)

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New Mexico

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ABSTRACT

Aircraft sampling penetrations of a low-yield nuclear cloud from a land-surface burst in Nevada were made at four altitudes, from 20 to 54 minutes after detonation. Samples from each of the four levels were radiochemically analyzed for 15 fission product isotopes. Other samples from each level were fractionated into seven particle size groups by settling in benzene. The individual size fractions were analyzed radiochemically and by gamma spectrometry. Particle size distributions and specific activities were measured in the untreated and artificially fractionated specimens of debris. Fallout samples were collected in trays along the fallout hot-line. The fallout samples were radiochemically and gamma spectrometrically analyzed.

The extensive radiochemical and physical data published by NRDL on the fallout samples (Reference 9) were used in conjunction with the cloud data to establish: (1) approximately 70 to 75 percent of Zr^{95} and the rare earth refractory fission products had fallen out of the cloud within 20 minutes of the detonation. Of the 25 percent remaining, about 15 percent later fell out locally and at intermediate distances; the remaining 10 percent resided in particles less than 18 micron diameter and was carried to larger distances. (2) Approximately 5 percent of Cs^{137} and Sr^{89} fell out of the cloud in the first 20 minutes. Of the Cs remaining in the 20-minute cloud, about 25 percent fell out locally and at intermediate distances; the remaining 70 to 75 percent was associated with particles less than 18 microns in diameter and was dispersed to larger distances.

The partitioning of 18 fission product chains between the cloud and the prompt fallout has been determined from the detailed radiochemistry of the cloud and fallout samples. All are intermediate between Zr and Cs in partitioning behavior.

The radiochemical composition of prompt fallout particulates can be systematized on the basis of a simple model employing the concept of fallout formation time.

The R value data for the cloud are satisfactorily fit by the relationship $R_{i,89} = (R_{95,89})^n$ where n varies between 0 and 1 for the different isotopes. The relationship is not extrapolatable to the composition of the fallout samples.

Three specific activity and particle size distribution behaviors can be discerned: irregulars in the cloud; irregulars in the prompt fallout; and spheres in the cloud.

The particle frequency functions for the irregulars in the cloud can be fit by $F(D) \propto /D^{3.2}$. The size distribution for spheres appears to be approximately log-normally distributed about a mean of 30 microns.

The specific activity of all isotopes in the cloud is highest in the smallest particles. S_{95} (fissions of Zr^{95} per gram) in the cloud decreases with increasing particle size but averages about 5×10^{13}, similar to the value in the most

intense prompt fallout samples. S_{137} in the cloud averaged 4×10^{14} fissions/gm compared to 1.2×10^{12} in the intense prompt fallout. The relationship between S_{95} and diameter is given by: $S_{95} \propto D^{-0.2 \pm 0.1}$. S^{137} follows no simple relationship with D over the entire size range but the distribution of Cs between particles $> 18\mu$ and $< 18\mu$ can be fit by $S_{137} \propto D^{-1}$. Data on the regulars (spheres) are tentative. The spheres exhibit a somewhat higher specific activity (S_{95}) than the irregulars. No more than 10 percent of the cloud fission activity is borne by spheres. Microprobe analysis demonstrates most spheres contain iron, with various quantities of Cr, Mn, Ni, and Zn, some of which show a tendency to be enriched relative to iron as particle size increases.

The importance of synthesizing data from cloud and surface sampling analysis programs is stressed. Isotopic fractionation is used as a tool in arriving at a partitioning between prompt and more remote fallout.

TABLE 3.1 INTENSITY PROFILE IN CLOUD

Altitude (Kft)	Intensity
9.5	1.00
10.0	1.53
10.5	2.15
11.0	2.99
11.5	3.69
12.0	4.47
12.5	5.26
13.0	6.30
13.5	7.19
14.0	8.62

TABLE 3.2 R VALUE SUMMARY OF CLOUD RELATIVE TO Sr^{89}

	9.5K	11K	13.5K	14K	Ave R
Sr^{90}	0.97	0.95	0.96	1.00	0.97
Y^{91}	0.89	0.75	0.66	0.61	0.70
Zr^{95}	0.64	0.53	0.28	0.173	0.292
Mo^{99}	0.65	0.51	0.29	0.167	0.29
Sn^{125}	1.02	1.01	0.93	0.89	0.92
Te^{129m}	0.95	0.91	0.98	0.76	0.82
Te^{132}	0.91	0.91	1.07	0.81	0.86
Cs^{137}	1.02	1.01	1.08	1.07	1.05
Ba^{140}	0.88	0.87	0.82	0.66	0.77
Ce^{141}	0.99	0.79	0.63	0.48	0.62
Pr^{143}	0.58	0.42	0.30	0.178	0.29
Ce^{144}	0.62	0.52	0.23	0.170	0.29
Nd^{147}	0.59	0.42	0.24	0.154	0.26

TABLE 3.12 RADIOCHEMICAL COMPOSITION OF PROMPT FALLOUT

	Zr^{95} R' Values				
	0-6m	6-20m		0-6m	6-20m
Sr^{89}	0.0317	0.100	I^{131}	0.083	0.95
Sr^{90}	0.107	0.40	Te^{132}	0.061	0.59
Y^{91}	0.512	0.82	*Cs^{136}	0.49	-
Mo^{99}	1.00	1.00	Cs^{137}	0.034	0.35
Zr^{95}	1.00	1.00	Ba^{140}	0.28	0.67
Ru^{103}	0.74	0.95	Ce^{141}	$0.46 \pm .15$	0.83
*Ru^{106}	0.08	0.40	Ce^{144}	1.06	1.00

In the above table, asterisked values have been divided by 1.6 to normalize for their increased yield in bomb spectrum fission. The values in the table for Sr^{89}/Zr^{95} = .0317 are estimated to be good to 10% for Sr^{89}, Sr^{90}, Y^{91}, Mo^{99}, Zr^{95}, Ba^{140}, and Ce^{144} and to ± 25% of the quoted value for the remaining isotopes, unless noted. The values for Sr^{89}/Zr^{95} = 0.1 are considerably less well established and are based exclusively on the lines drawn through the data points of Figures 3.6a and 3.6b.

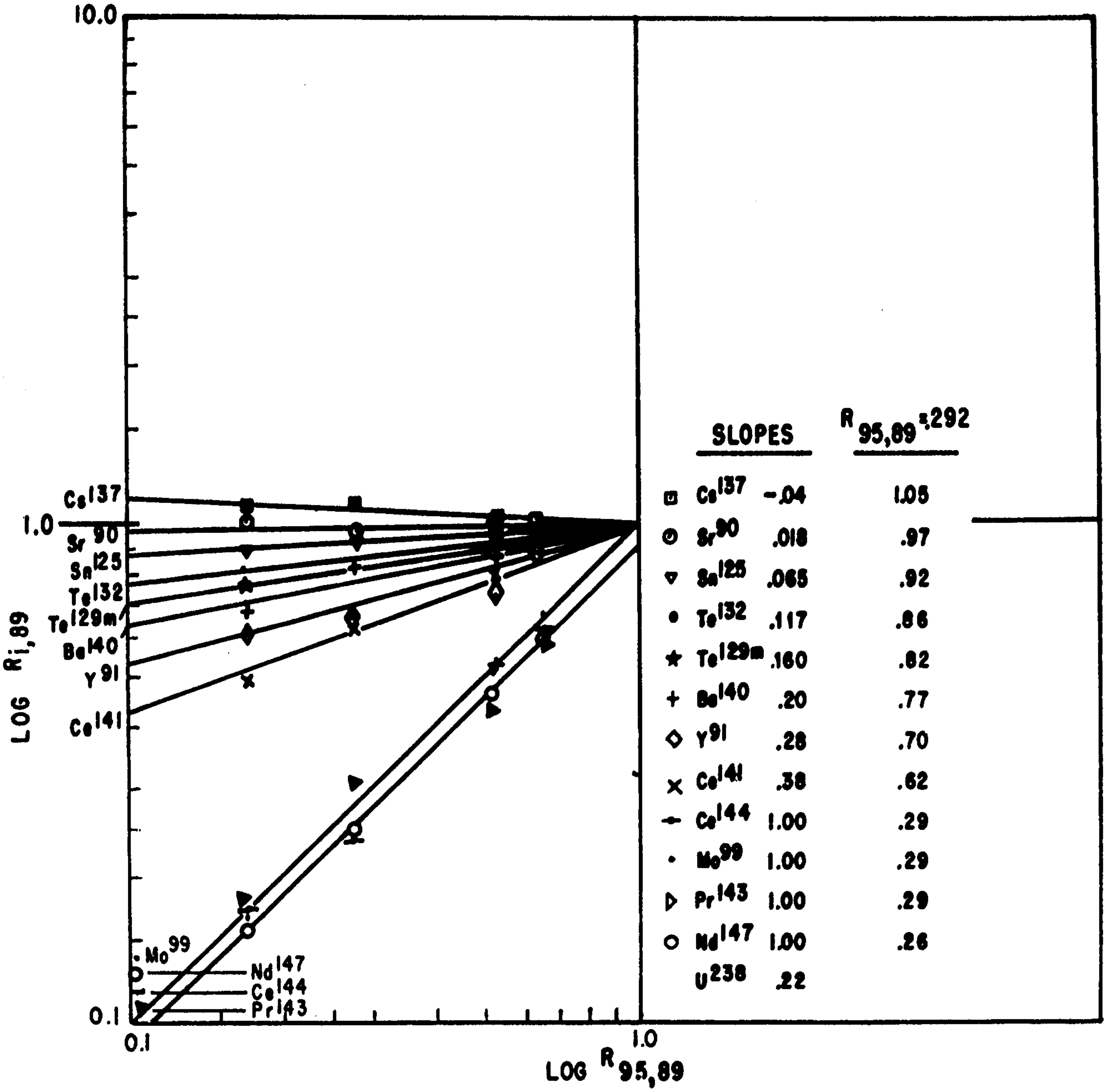

Figure 3.1 Fractionation plots cloud samples.

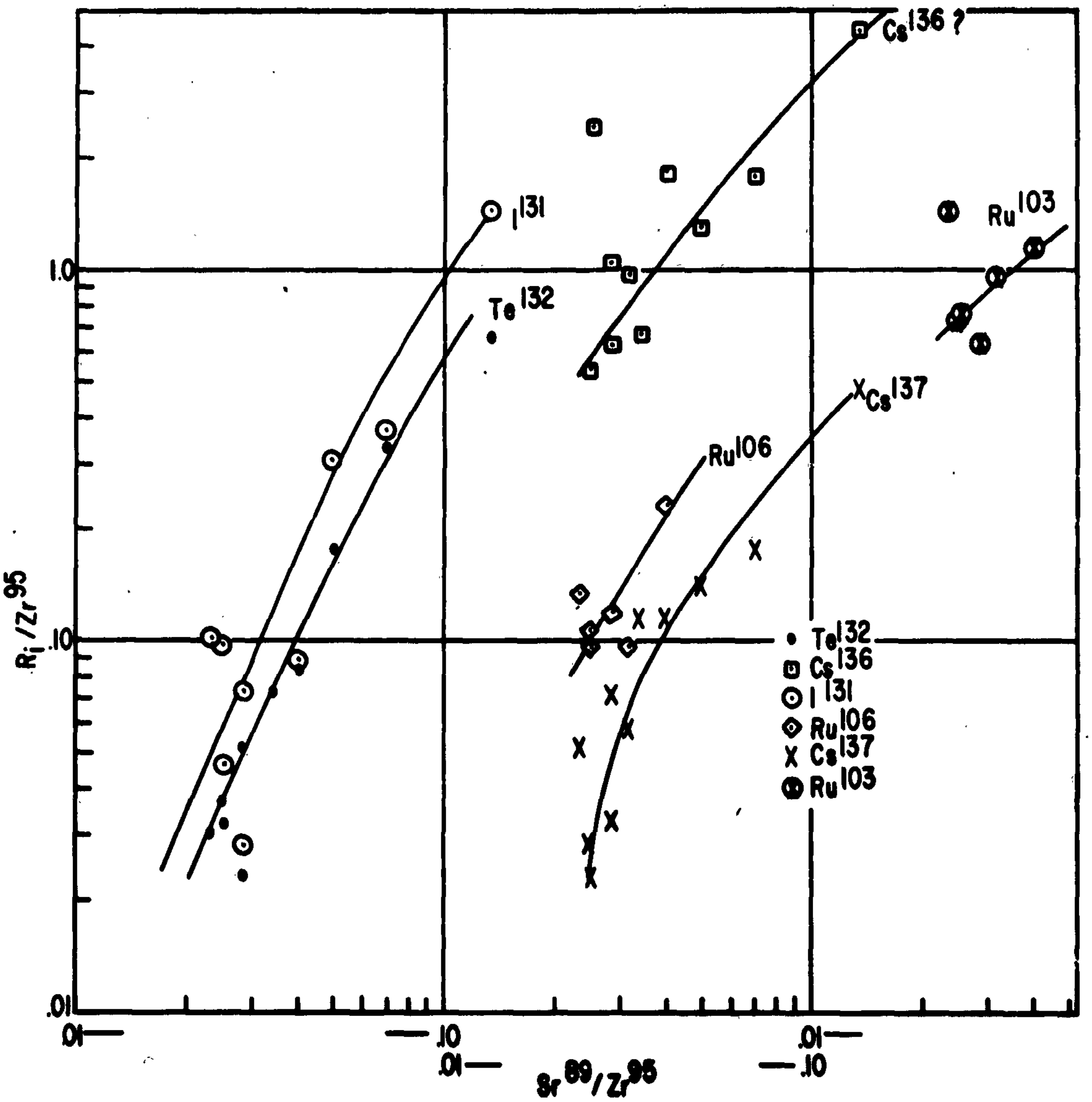

Figure 3.6b Fractionation plots, fallout samples.

4.5 PARTICLE SIZE AND MASS FREQUENCY CURVES FOR THE EVENT

The salient features of the particle size and mass frequency curves for the event can be deduced from a synthesis of NRDL and our data. A crude normalization might be provided by using the fact that there are approximately 400 tons of debris in the 20-minute cloud and of the order of 1,000 tons of high specific activity prompt fallout.

The particle size distribution found in the 20-minute cloud appears to be given by $K/D^{+3.25}$ to good approximation between 1 micron and the cloud cut-offs (100 to 160 microns). This implies a mass distribution as $D^{-0.25}$ in the cloud. The NRDL data (see summary in Table 3.11) exhibit a median mass diameter of 700 to 1,000 microns in the more intense fallout (it is lower elsewhere) and a median activity diameter (MAD) somewhat [illegible] than the MMD. Clark, in reference [illegible] has observed that the fraction of radioactive particles increases with size in the fallout, being about 25 to 50 percent in the larger size fractions (>200μ). This finding is in accord with our observation that the mean specific activity of the prompt fallout $S_{95} = 5.7 \times 10^{13}$, whereas the specific activity of the lava particles, which represent the main active component, is 1.88×10^{14} or approximately three times higher. Further, the specific activity of lava particles is reasonably constant.

DISCUSSION

The Johnie Boy event was detonated one foot below ground at the Nevada Test Site on 11 Jul 62 at 0945 hours. The cloud reached a height of approximately 14,000 feet MSL and ground zero was 5,200 feet MSL.

Three B-57 aircraft from the 1211th Sampling Squadron at Kirtland Air Force Base, New Mexico, performed the cloud penetrations. Two of the aircraft were airborne prior to H-hour and penetrated the cloud from H+20 to H+33 minutes. The third aircraft was dispatched at H+20 minutes and penetrated the cloud at H+48 and H+54 minutes.

The data as recorded by the crew during the cloud penetrations are presented in Table A.2.

Photographs of the cloud at H + 25 seconds, H + 1 minute 30 seconds, and H + 2 minutes 30 seconds, are shown in Figures A.1 through A.3.

After the samples were removed from the aircraft wing tips, they were monitored and placed in lead pigs. The filter sample from a single wing tip tank is divided into a half and two quarter samples. Each of these sections was placed into a single lead pig.

The data obtained from the samples immediately after their removal from the aircraft appear in Table A.3. The data obtained on the samples at H+24 hours appear in Table A.4.

TABLE A.1 DOSE AND DOSE RATE DATA FROM CLOUD PENETRATIONS

MSL Altitude of Penetration (ft)	14,000	11,000	11,000	9,500	12,000	13,500 rising to 14,000
Penetration Time (min)	H+20	H+20	H+25	H+33	H+48	H+54
Peak Dose Rate in Cloud (r/hr)	200	60	60	6	0.1	8
Average Dose Rate in Cloud (r/hr)	75	10	30	4	0.05	4
Time Spent in Cloud (sec)	17	10	15	30	68	83
Total Dose (R)	0.6	0.2	0.3	0.45	0.01	0.35

TABLE A.2 DATA EXTRACTED FROM PILOTS DATA CARDS

Aircraft Number	827	842	842	842	245	245
Pass Number	1*	1**	2**	3***	1****	2****
Altitude (feet)	14,000	11,000	11,000	9500	12,000	13,000 rising to 14,000
Air Temp. (°C)	18	20	22	21	24	22
Time After H-Hour (minutes)	20	20	25	33	48	54
RASCEL Dose Rate In Cloud (r/hr) Peak	200	60	60	6	0.1	8
RASCEL Dose Rate In Cloud (r/hr) Avg.	75	10	30	4	0.5	4
Time in Cloud (sec.)	17	10	15	30	68	83
INTEGRON Dose (r)	0.6	0.2	0.3	0.45	0.01	0.35
RASCEL Cockpit Background (out of cloud) Dose Rate (r/hr)	0.4	0.05	0.1	0.1	0.01	0.15
Wing Tip Ion Chamber Dose Rate (r/hr)	1.2	0.05	0.05	0.2	0.23	0.47
IAS (knots)	250	250	250	250	250	250
Readings After Landing						
RASCEL (r/hr)	0.19	0.05	—	—	0.12	—
INTEGRON (r)	0.7	0.5	—	—	0.49	—
Ion Chamber (r/hr)	0.8	0.14	—	—	0.35	—
Time of Reading (min.)	H+33	H+50	—	—	H+75	—

* One penetration with both tip tanks open.

** Both passes made with left tank open, therefore, they represent one sample.

*** Only the right tip tank open.

**** Both penetrations made with both tanks open. The altitude variation of the second penetration was an attempt to follow the top of the cloud.

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